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NASA Probes Detect "Smoking Gun" to Solve Radiation Belt Mystery

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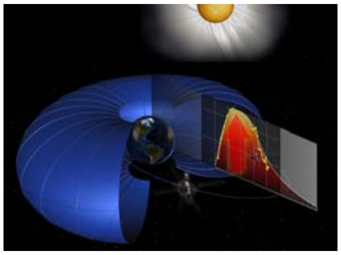

This artist's conception shows an enhancement in the electron intensity in the heart of the radiation belts where they are accelerated. The reddish area shows the shape that is characteristic of local acceleration and the yellow curve shows the actual observations as obtained by the Van Allen Probes. Image courtesy of Geoff Reeves and Mike Henderson, Los Alamos National Laboratory.

DURHAM, N.H. — Space scientists have discovered a massive particle accelerator in the heart of one of the harshest regions of near-Earth space, a region of super-energetic, charged particles surrounding the globe called the Van Allen radiation belts.

Derived by measurements taken by a University of New Hampshire-led instrument on board NASA's Van Allen Probes mission, the findings answer a longstanding question in radiation belt science by showing that the acceleration energy is inside the belts themselves rather than from a source farther away: particles are sped up by a local kick of energy, buffeting them to ever faster speeds like a tetherball circling a pole and gaining momentum with each perfectly timed punch.

The revelation is akin to discovering that hurricanes grow from a local energy source, such as a region of warm ocean water. In the case of the radiation belts, the source is a region of intense electromagnetic waves.

Knowing the location of the acceleration will help scientists make better predictions of space weather conditions in this area of intense radiation that can be risky for

Earth-orbiting satellites. The results were published in the July 25, 2013 issue of the online journal Science Express.

“Energetic electrons in the Van Allen radiation belts have been implicated in past satellite failures and so they are often referred to as 'killer electrons',” says UNH astrophysicist Harlan Spence, co-author on the Science paper and principal investigator on the Energetic Particle, Composition, and Thermal Plasma (ECT) instrument suite on board the twin Van Allen Probe spacecraft that made the precision particle measurements.

Adds Spence, “A 50-year mystery of the radiation belts is, where, when and how these electrons are energized. With the Van Allen Probes, we have gone to the very scene of the crime, so to speak, and witnessed the unique, unambiguous fingerprints of a local acceleration process for the first time, revealing the culprit acting to create killer electrons.”

The Van Allen belts are two donut-shaped regions of high-energy particles trapped by Earth's magnetic field. At the time of their discovery in the 1950s they were thought to be relatively stable structures, but subsequent observations have shown they are dynamic and mysterious.

For example, sometimes after a solar storm the number of particles (protons and electrons) that populate the belts can increase dramatically and their speeds can approach the speed of light or become "relativistic"– about 186,000 miles per second. However, at other times after similar space weather events, the particles decrease in number and speed, or conditions seem to just stay the same.

Until the 1990s, we thought that the Van Allen belts were pretty well-behaved and changed slowly," says Geoff Reeves, lead author on the paper and deputy principal investigator on ECT at Los Alamos National Laboratory in Los Alamos, N.M. "With more and more measurements, however, we realized how quickly and unpredictably the radiation belts changed. They are basically never in equilibrium, but in a constant state of change."

In order for scientists to understand such changes better, the Van Allen Probes were designed to fly straight through this intense area of space. When the mission launched in August 2012, it had as one of its top-level goals to understand how particles in the belts are accelerated to ultra-high energies. The goal of the Van Allen Probes mission is to provide understanding – ideally to the point of predictability – of how populations of relativistic electrons and penetrating ions in space form or change in response to variable inputs of energy from the sun and distinguish between two broad possibilities on what speeds up the particles to such amazing speeds: radial acceleration or local acceleration.

In radial acceleration, particles are transported perpendicular to the Earth's magnetic fields from areas of low magnetic strength far away to areas of high magnetic strength nearer Earth. The laws of physics dictate that the particle speeds in this scenario will correlate to the strength of the magnetic field. Thus, the speed would increase as the particles move toward the Earth, like a rock rolling down a hill gathers speed simply due to gravity. The local acceleration theory posits that the particles gain energy from a local energy source more similar to the way hot ocean water spawns a hurricane above it.

The ECT team found they could distinguish between these two theories when they observed a rapid increase in the radiation belts on Oct. 9, 2012. The observations did not show an intensification starting at high altitude and moving gradually toward Earth.

Instead, they showed an increase that started right in the middle of the radiation belts and gradually spread both inward and outward, implying a local acceleration source. The research shows that the local energy comes from electromagnetic waves coursing through the belts.

“These new results go a long way toward answering the questions of where and how particles are accelerated to high energy,” says Mona Kessel, Van Allen Probes Program Scientist at NASA Headquarters. “One mission goal has been substantially addressed.”

The challenge for scientists now is to determine which waves are at work. Such a task will also be helped along by the Van Allen Probes, which were also carefully designed to measure and distinguish between the numerous types of electromagnetic waves.

Co-authors on the Science paper include researchers from the University of Colorado at Boulder, NASA Goddard Flight Center, the Aerospace Corporation, the University of California-Los Angeles, and the University of Iowa.

The University of New Hampshire, founded in 1866, is a world-class public research university with the feel of a New England liberal arts college. A land, sea, and space-grant university, UNH is the state's flagship public institution, enrolling 12,200 undergraduate and 2,300 graduate students.

The Johns Hopkins University Applied Physics Laboratory built and operates the twin Van Allen Probes for NASA. The Van Allen Probes comprise the second mission in NASA's Living With a Star program, managed by Goddard, to explore aspects of the connected sun-Earth system that directly affect life and society.

For more information about the Van Allen probes, visit: www.nasa.gov/vanallenprobes/

For more information on the Energetic Particle, Composition, and Thermal Plasma (ECT) instrument suite, visit: http://rbsp-ect.sr.unh.edu/team.shtml

Image to download: http://www.eos.unh.edu/newsimage/vanallenprobes_lg.jpg

Caption: This artist's conception shows an enhancement in the electron intensity in the heart of the radiation belts where the

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